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October 26, 1992

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87-268

Dr. Irwin Dorros
Co-Chairman, Technical Subgroup
Chairman, Systems Subcommittee, ACATS
Executive Vice President, Technical Services
Bellcore
290 West Mt. Pleasant Avenue, Room 1E309
Livingston, New Jersey 07039

Dear Joe and Irwin:

In response to Mr. Wiley's August 21 letter, Zenith and AT&T hereby submit to the Technical Subgroup of the Special Panel a description of improvements in the DSC-HDTV system that we would like to have considered by the Special Panel and the Advisory Committee. Our description includes improvements already implemented which could be tested now, improvements currently under way which could be included in field testing early next year, and additional improvements that could be made in the future. We also describe our method for incorporating the ATSC T3/186 audio and ancillary data features into our system, as Mr. Wiley's letter requests.

The attached document gives a complete and detailed technical description of the improvements and the expected effect of these changes on all performance parameters of the system. All of the modifications represent improvements in the implementation of the system as certified by SS-WP1, and do not constitute substantial changes to the certified system.

At this stage in the development of state-of-the-art digital video compression technology, the implementation of prototype equipment is subject to ongoing, virtually continuous improvement. With the move to all-digital

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systems occuring just two to three years ago, it should not be surprising that a series of relatively modest adjustments and modifications could result in significant improvements in system performance during the months since ATTC testing began for the various all-digital systems.

In the case of the DSC-HDTV system, this expected progression of improvements has been more pronounced because of difficulties and delays encountered in the development of the prototype equipment prior to entry into the test center. These difficulties kept the Zenith/AT&T team from fully meeting its internal schedules for integrating, testing and tuning the prototype system. As a result, we were unable to do the planned and necessary extensive tuning and optimizing of the total system before we had to move into the test center. At the time, we felt it was mandatory to enter the test center on schedule, and we did not seek any delay in which to complete system integration testing to our satisfaction.

In spite of our failure to complete such tuning and testing prior to entering the ATTC, our system performed very well in most respects. However, the inadequate tuning did cause a negative impact on some aspects of video quality and video soft-coding performance. These problems were compounded by an even higher than expected level of characteristic noise in the 787 source test materials, as well as one or more types of other unexpected noise which we believe may also have been present in the source materials. We believe our coder spent a significant portion of its bit budget coding this noise, with a resulting negative impact on picture quality and video soft-coding performance.

Since leaving the test center in late May, we have done much more careful tuning of the system and have also made a series of relatively minor modifications and improvements which in the aggregate have resulted in significantly improved system performance. The attached document describes these improvements in detail and attempts to quantify and evaluate their impact on system performance. It explains how the improvements have overcome previous performance shortfalls and clearly demonstrates that they have not come at the expense of other important aspects of system performance.

We are anxious to do all we can to facilitate the thorough evaluation of our improved system by the Technical Subgroup, the Special Panel and ACATS itself. We would be pleased to provide any amplification or further explanation of the improvements and their impact on system performance. Video tapes of processed video, comparing ATTC-version to present-version system performance can be provided. Members of the Technical Subgroup are welcome to visit either Zenith or AT&T Bell Labs and to conduct any experiments they wish using our system. In short, we are ready to cooperate in any approach the Technical Subgroup might devise for obtaining a fair and thorough evaluation of the improvements to our system.

As you know, we have been strong advocates of limited supplemental laboratory testing of the improved ATV systems. While we are completely open to any other approach for evaluating improvements, we continue to believe that much more reliable assessments will be achieved, to the benefit of all parties in the process, if supplemental testing can be accommodated within the Advisory Committee's approach. (See my August 13 and October 13 letters to Mr. Wiley.)

We understand that the Technical Subgroup's assessment of the proponents' system improvements will be an essential factor in the Advisory Committee's determination of the need for and the practicality of further laboratory testing. We're submitting this description before the November 2 deadline in the hope that a head start by your committee in evaluating the improvements in at least one of the systems will help make it possible ultimately to include limited supplemental testing as part of your evaluation process. Along with our description of improvements, we've included a revised proposed list of supplementary tests as a starting point for a discussion of exactly what tests would be required to assess the improvements and their potential impact on other aspects of performance.

We urge the Technical Subgroup to accept these improvements to the Zenith/AT&T DSC-HDTV system for consideration by the Special Panel and the Advisory Committee. By so doing, their decisions and recommendations can be based on the most accurate and up-to-date information regarding the performance and capabilities of our system. We further urge the Technical Subgroup to recommend to the Advisory Committee leadership that limited supplemental laboratory testing of these improvements be conducted.

Sincerely,

Robert Graves

Attachment

cc: R. E. Wiley
Technical Subgroup Members
Other Proponents (on November 2)

DSC-HDTV

System Improvements

Zenith
Electronics
Corporation

AT&T

October 26, 1992

Table of Contents

1. Introduction

This document gives a complete and detailed technical description of implemented and planned improvements in the DSC-HDTV, as well as an assessment of the expected effect of these changes on the performance of the system. All of the modifications proposed here for consideration by the Special Panel represent improvements in the implementation of the system as certified by SS-WP1, and do not constitute substantial changes to the system. The system remains essentially the same as that described in the DSC-HDTV certification submission dated September 23, 1991.

As discussed in the cover letter to this document, state-of-the-art digital video compression technology is subject to almost continuous improvement at this stage in its development. In the case of DSC-HDTV, this expected progression of improvements has been even more pronounced, because of delays and difficulties experienced by the Zenith/AT&T team prior to entry into the test center last February. In order to enter the test center on schedule, we had to truncate prematurely the planned integration, tuning and testing of the overall system.

Despite these problems, our system performed quite well in most respects. However, the inadequate tuning and optimizing of the system did cause a negative impact on some aspects of picture quality. These problems were compounded by an even higher than expected amount of characteristic noise in the 787 source materials, as well as one or more types of other unexpected noise which we believe may also have been in the source materials. (We would be happy to share our analysis of similar, same-vintage materials, or participate in any effort the Advisory Committee might deem appropriate to analyze the impact of such noise on the testing process for 787 systems.)

Since leaving the test center in late May, we have done much more careful tuning of the system, and have also made a number of relatively modest improvements which in the aggregate have significantly improved system performance. The sophisticated design of our state-of-the-art system permits it to benefit greatly from such careful tuning, and we worked hard to build this kind of flexibility into the prototype hardware and software.

This document describes these improvements in detail and attempts to quantify and evaluate their impact on system performance. It explains how the improvements have overcome previous shortfalls without compromising other important aspects of system performance.

Section 2 describes improvements that have already been implemented in the system and that could be evaluated in a program of supplemental testing. These improvements include:

- Vertical noise coring in the video source processor
- Improvements to the quantizer vector selector codebook
- More optimized choices of quantizers, perceptual weights, scale factors, and variable length codes
- Use of a variable offset in the digital leak calculation
- More effective error concealment implementation
- Improved buffer control
- Reduced pilot carrier level
- Change in offset frequency to eliminate subdued vertical color stripe in co-channel NTSC receivers, and reoptimized dispersion, giving a reduced peak-to-average power ratio

Section 3 describes actions to correct two hardware problems in the system which did not affect the performance of the system in the test center, but were noted in the draft report by ATTC.

Section 4 summarizes these improvements, quantifies the effect of each, and demonstrates the significant overall gain in system performance and results. It also describes the substantial improvements in soft-coding performance expected to result from the coding efficiency gains brought by these improvements.

Section 5 describes improvements that will be implemented before the ACATS field testing planned for early next year, including:

- Spatially adaptive leak to vary the leak value within a frame in the encoder
- Modified adaptive equalizer to permit faster update based on data

Section 6 describes further improvements that can be made to the DSC-HDTV system after field testing.

Section 7 demonstrates how a flexible assignment scheme can be employed in the DSC-HDTV data frame using headers and descriptors to provide desirable services and features such as the audio and ancillary data services identified in the ATSC T3/186 document.

Section 8 contains a careful analysis of the supplementary tests that would be required to measure the improvements already implemented in the DSC-HDTV system, and to ensure that such improvements have not come at the expense of other aspects of performance.

Section 9 includes a summary and conclusions regarding improvements to the system. It is followed by an appendix describing two related developments under way for the DSC-HDTV system: the ability to provide two HDTV programs over a single 6 MHz cable TV channel, and the development of a prototype consumer VCR using Super-VHS technology which can record and play back the compressed DSC-HDTV data signal.

2. Improvements To Date

This section summarizes improvements already made to the video source processor, the video coder/decoder and the transmission system (see Figure 1). The DSC-HDTV system, at the time of ATTC testing, contained:

- many parameters which were not optimally chosen, and
- several shortcuts (to enter the test center on time) which limited its performance, but which did not change the inherent algorithm that was certified.

The following improvements were made without changing the basic algorithm, and there were no changes to the channel data format. Each of the improvements and its separate impact on the performance of the coder are first described one at a time. In Section 4, the overall performance of the system after incorporating all the improvements is assessed. At this time, the trade-off between picture quality and transmission performance is being readjusted to achieve better soft-coding. Since the results of this trade-off are not completely in hand, the overall performance improvement in the final system may be slightly different from the assessment given today.

Figure 1. DSC-HDTV Block Diagram

2.1. Vertical Noise Coring in Video Source

Background

Video coders exploit redundancy in the source image. Video source noise tends to mask the redundancy in the video image and burdens the video coder with uncorrelated information. One technique used in the DSC-HDTV system to ameliorate the effects of low level source noise is adaptive noise coring. The function of noise coring in the DSC-HDTV system is to remove low levels of high frequency noise adaptively. The visual effect of the adaptive coring used in the DSC-HDTV system is almost unnoticeable to the human eye, however, it removes noise to which the encoder might otherwise respond, thereby improving coder efficiency.

Problem

Only coring of horizontal source noise was employed in the hardware delivered for ATTC testing. Vertical noise was not reduced. This remaining source noise reduced the efficiency of the coder causing visible artifacts when coding very noisy source material such as the 787 camera-generated scenes used at ATTC.

Solution and Improvement

Vertical source noise coring has been added to the DSC-HDTV system. By adding vertical coring to the system, the video coder more efficiently codes the "real video" instead of wasting bits on the noise, and picture quality is improved.

2.2. Coder/Decoder Improvements

2.2.1. Quantizer Vector Selection Codebook

Background

Discrete Cosine Transform (DCT) coefficients are either quantized or dropped in the encoder loop. The majority of the compression is achieved by dropping coefficients. A typical DCT quantizer/drop selection pattern is shown in Figure 2. The numbers represent a quantizer index (out of 7 possible quantizers) and D stands for drop. A pattern is chosen from the code book which simultaneously minimizes the bit-rate and the deviation from the allocated picture distortion. For example, most high frequency (lower right corner) DCT coefficients are dropped because the picture error can be reached by zeroing these coefficients.

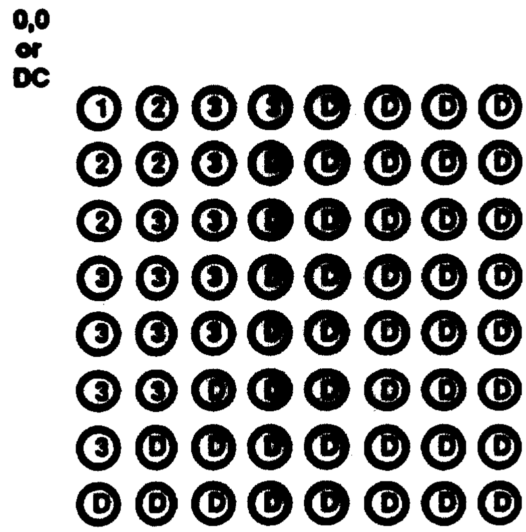

Figure 2. Typical Quantizer Selection Pattern

Problems

The old codebook did not contain enough vectors to allow quick correction of small quantization errors. This resulted in:

- Relatively slow correction of accumulated quantization errors, giving a "twinkle" effect in still pictures.
- Visible block artifacts in:
  - high detail still pictures
  - pictures with high levels of source noise
  - high frequency zone plates
- Overall reduction in coding efficiency

Solutions

The improved code book has additional vectors which select small subsets of DCT coefficients for quantization. A typical new selection vector is shown in Figure 3. The implementation of this change was an update to a table in the encoder and decoder. The effect of this improvement was to reduce greatly any slowly varying changes to the quantization error and to provide an overall increase in picture quality due to a reduction in the number of bits wasted to send coefficients that were quantized to zero.

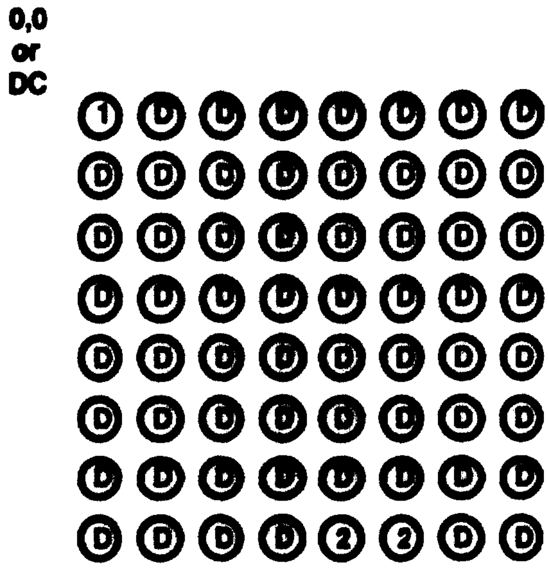

Figure 3. New Type Of Selection Pattern With Small Coverage of High Frequencies Only

Improvements

- Removal of "twinkle" in stills
- Removal of many block artifacts from high frequency zone plates
- Greatly improved coding of pictures with source noise
- Overall increase in coding efficiency

2.2.2. Quantizers, Perceptual Weights, Scale Factors, and VLCs

Background

The perceptual weights determine the amount of quantization error that is allowed for each coefficient, and a variety of non-uniform quantizers are available to achieve the allowed error. The scale factors optimize the average efficiency of quantization. Variable length codes (VLCs) are assigned to quantized coefficients, selection vectors and motion vectors to achieve additional compression.

Problems

The quantizers, perceptual weights, and VLCs were not optimally set in the ATTC-tested system, resulting in visible artifacts for some coded scenes and significant loss of overall efficiency. In particular,

- The combination of suboptimal chrominance scale factors and quantizers occasionally resulted in visible artifacts where high chrominance levels were combined with low luminance values.
- Loss of resolution and busyness in and around areas with saturated colors were seen.

Solutions

The following changes were implemented by modifying the contents of several tables in the encoder and decoder.

- The perceptual weights were changed to reduce high frequency coefficient quantization error.
- Quantizers were modified to provide a better match with the new perceptual weights and selection vector codebook.
- Additional new quantizers were provided for selection by the quantizer vector selector.
- New variable length codes were generated for the new quantizers and selection vectors.

Improvements

- Significant reduction in saturated color artifacts
- Reduction in distortion for typical pictures (at the same bit-rate) by 50%, or
- Increase in proportion of 2-level segments (at the same target distortion) by 50%
- Reduction in picture distortion for a high frequency moving zone plate by a factor of three.

2.2.3. Leak

Background

The points in the encoder and decoder loops where the leak factor is applied are shown in Figure 4. The leak factor (referred to in our certification document as DF-Factor) controls the amount of original image which is mixed with the displaced frame difference (DFD). Leak provides the following benefits:

- Quicker recovery from channel errors
- Quicker channel change
- Flushes quantization error from encoder loop
- Enables VCR trick modes

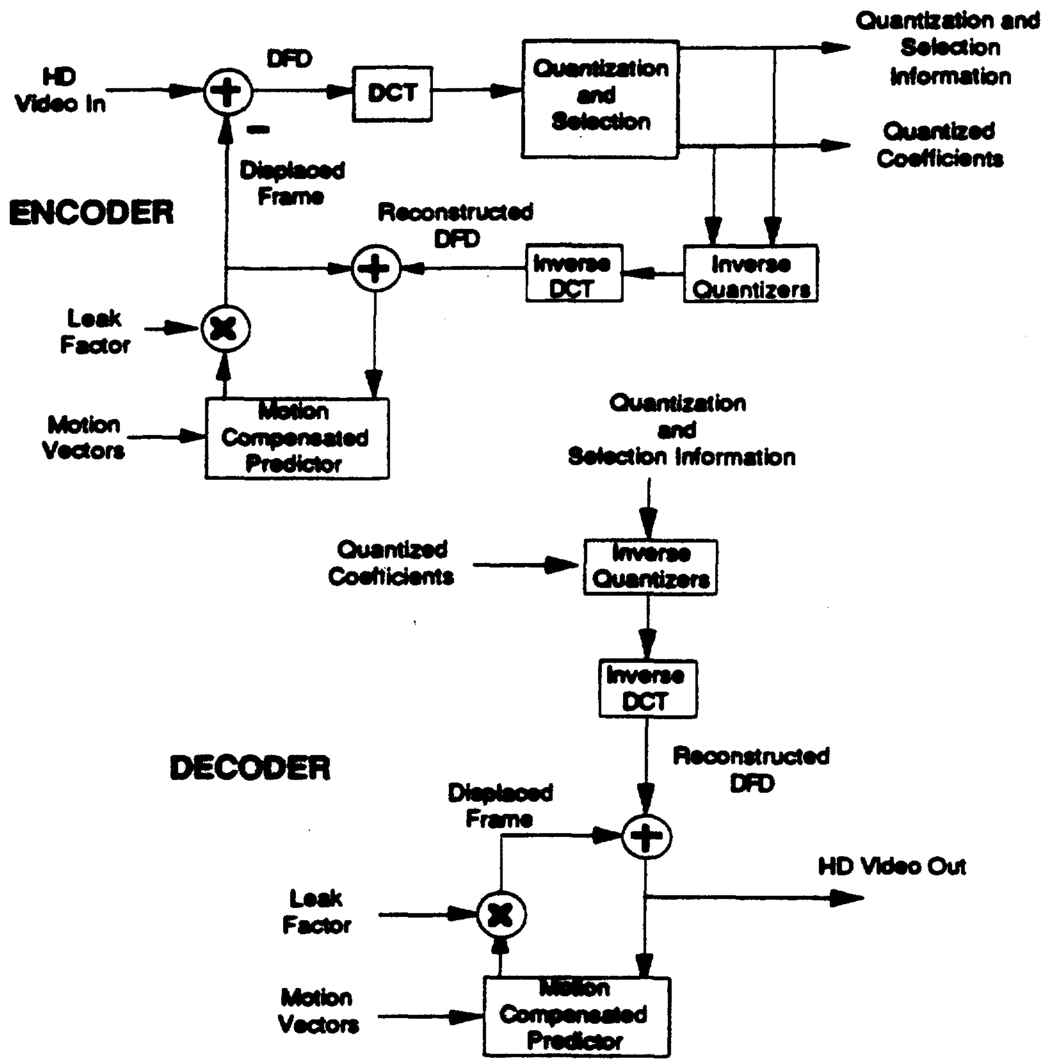

Figure 4. Encoder And Decoder Loops

The application of leak using limited precision integer arithmetic can cause errors to persist in the loop. Proper fixes for this so called "limit cycle" problem are known in the literature.*

Problems

Due to lack of pre-test tuning time, a suboptimal fix was implemented which added a cyclic offset to the frame mean value used in the encoder.

- Mean offset caused a periodic increase in the average value of the displaced frame difference (DFD) which resulted in temporal variation in the DC coefficient energy.
- Overall coding efficiency was decreased.
- Slowly varying and periodic changes ("breathing") to DC coefficient quantization error were visible in very complex scenes such as moving zone plates and rotating radial resolution charts.
- Maximum leak was limited to 15/16, forcing use of unity leak (perfect prediction) for six of seven frames. Thus, leak was applied once in seven frames.
- Periodic leak cycle caused oscillations in the buffer control system.
- Uncorrected transmission errors did not decay rapidly, due to application of the leak factor only once in seven frames.

Solutions

The improved system does not offset the mean but applies a variable offset in the leak calculation. The leaked value is calculated by shifting the original value (dividing by powers of two) and then subtracting this from the original value. The offset is applied to the shifted value. The sequence of offset values is common to both encoder and decoder, which are synchronized by a bit in the global data. Thus, leak calculation error is reduced without adding to the DC coefficient amplitude.

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* See, for example, *Digital Pictures: Representations and Compression*, A. N. Netravali and B. G. Haskell.

Improvements

- Removal of "breathing" in high frequency zone plate
- At the same level of picture distortion, the amount of 2-level data is increased by about 50%, or
- At the same amount of 2-level data, the picture distortion is decreased by about 50%

2.2.4. Error Concealment

Background

Error concealment in the DSC-HDTV system is performed by replacing missing or erroneous pixels with the pixels from a previous frame. The compressed video data is packaged into segments in preparation for transmission. Each segment is provided with Reed-Solomon forward error correction and modulated using 2-level or 4-level signaling. The encoder selects important segments to be modulated using 2-level signaling, since they are received more reliably. In the decoder, a given segment is assumed to be entirely correct or entirely erroneous as indicated by the error correction system. A lost segment affects one or more slices (64H x 48V blocks).

Problems

Due to lack of pre-test tuning time, the method for pixel replacement in the ATTC-tested system was simply to zero the erroneous DCT coefficients and use the motion vectors from a previous frame if they were also in error. For example, if the leak was 15/16, the replacement pixels in the ATTC-tested system were attenuated to 15/16th of their original values. However, exact pixel replacement requires unity leak to avoid attenuating the replacement pixels.

- The visual effect of pixel attenuation in the old system is a fading to gray during heavy channel impairments.

Solution

- The leak is set to one for any 16 x 16 pixel block which was replaced in the decoder loop

Improvements

- Excellent error concealment for virtually all stills
- Good error concealment for all video when motion estimates are good
- Provides much more usable pictures when all 4-level data is lost

2.2.5. Buffer Control

Background

The buffer control uses the buffer fullness and complexity of the current frame to compute. the allowed distortion for the current frame. This computation is done only in the encoder. A buffer fullness level is sent to the decoder to synchronize its buffer to the encoder. Scene changes are also detected and, for scene-changed frames, the allowed distortion is increased to prevent buffer overflow. This increased distortion is not perceptually visible.

Problems

- Improper choice of scene change parameters caused some scene changes to take several frames to settle to full quality
- The buffer control in the ATTC-tested system had to operate under additional constraints due to two decoder inefficiencies:
  - A lower limit on the number of bits which could be used to code a particular HD frame
  - A lower limit on the maximum buffer fullness level

  These constraints adversely affected difficult scene changes and caused visible distortion on some pictures.
- The decoder did not use the buffer fullness level, causing delay between audio and video to be variable.

Solutions

- Better choice of buffer control parameters
- Increasing the efficiency of the decoder hardware
- Controlling the relative delay between the audio and video display to be within one frame time by use of the encoder buffer fullness value in the decoder

Improvements

- Scene changes now settle imperceptibly
- Target distortion is stable
- Audio and video delay are constant and equal

2.3. Transmission System Improvements

This section describes improvements made to the Transmission System (see Figure 1).

2.3.1. Reduction in Pilot Level

Background

In order to achieve maximum robustness, the DSC-HDTV signal utilizes a pilot carrier located at approximately 345 kHz from the lower band edge. The pilot serves as a reference on which the carrier recovery loop can lock and hold even in heavily impaired conditions. With the pilot, the carrier recovery loop holds lock even through fades and other causes of data loss. The pilot makes the DSC-HDTV carrier recovery insensitive to ghosts, noise and interference. The benefit of the pilot comes at the expense of slightly more power and potentially more upper-adjacent interference into NTSC. Co-channel interference into NTSC is not a problem because the pilot sits very far down on the vestigial sideband filter of the NTSC receiver and its interference contribution is negligible compared to the rest of the ATV signal.

Problem

During internal testing of the DSC-HDTV system, it was found that the pilot level was unnecessarily high and was lowered for the 2-level (W1) data prior to ATTC testing, as documented in the 2/25/92 letter to Birney Dayton, Chairman SS/WP1. Even with the documented change, the pilot was still suspected to be unnecessarily strong, but time pressures precluded further testing and refinement before delivery of the hardware for ATTC testing on 2/10/92.

The pilot causes slightly more upper adjacent interference into NTSC at the moderate and weak levels compared to systems without a pilot. The excessively high pilot level also contributes to unnecessary signal power.

Solution and Improvement

Further testing shows that the pilot can be lowered an additional 3 dB, for both W1 and W2 data, without any detrimental effects to system performance. In fact, the carrier recovery loop had a 16 dB excess margin over the recovery of reliable data. The reduction of pilot power by 3 dB still maintains 13 dB excess margin for the carrier recovery loop while at the same time lowering the DSC-HDTV power and improving upper adjacent interference into NTSC. The pilot reduction of 3 dB will improve upper adjacent performance into NTSC by 3 - 6 dB. This will vary among individual NTSC receivers, depending on the interference mechanisms in each.

2.3.2. Change in Offset Frequency And Dispersion

Background

DSC-HDTV transmits data in an "NTSC-like" data frame. Data is packetized and transmitted in segments corresponding to the NTSC line time. For synchronization, a fixed "segment sync" is transmitted at the beginning of every segment. The segment sync provides reliable data segment timing recovery even under heavy impairments. An additional benefit of the segment sync is that by providing reliable segment timing information, the complexity of other parts of the receiver is reduced (e.g. vertical sync recovery). Since the segment sync is transmitted at an NTSC line rate, it causes fixed pattern interference into an NTSC co-channel. This fixed pattern interference can show up in luminance and/or chroma.

Luminance interference into the NTSC co-channel from the segment sync is visible only at very high levels of impairment. Actually, since the segment sync is transmitted using the lower power 2-level data, the interference appears as a "clean" area where there is less interference compared to surrounding areas with noise-like interference. It isn't until very high levels of interference that a "character" of the segment sync interference appears. In the DSC-HDTV system, the visibility of this "clean" area is minimized by using time dispersion at the transmitter. Time dispersion changes the phase relationship of the transmitted signal and causes surrounding data pulses to be mixed into the fixed segment sync, thereby randomizing its co-channel interference visibility. Dispersion is simply accomplished with a linear filter with flat magnitude response and non-linear phase response. At the receiver, the inverse filter is used.

Problems And Manifestations

- By nature of last minute changes to the segment sync chosen (see 2/25/92 letter to Birney Dayton), and the precise offset chosen during ATTC testing, co-channel chroma interference showed up as a subdued vertical color stripe in the NTSC receivers.

- The dispersion used in the DSC-HDTV system for testing was optimized for the segment sync before the changes in the 2/25/92 letter. Since the dispersion was implemented in the SAW filters, there was no time to re-optimize it before ATTC testing. As a result, the dispersion used for testing did not help in "hiding" the luminance interference caused by the segment sync. In addition, we have found that dispersion increased the peak-to-average ratio of the DSC-HDTV signal by approximately 1.5 dB.

Solutions and Improvement

We propose an additional 30 Hz offset in the transmitter carrier frequency to eliminate the vertical color stripe by putting it into the "Fukinuki hole". This method was born out in a test (#055) conducted at the ATTC where the interference during the normal 30 Hz offset test was raised and the color stripe disappeared. The expert observers of this test described the effect as "a significant improvement to the Test 16 co-channel standard".

As an improvement, the dispersion has been reoptimized. This will not significantly change the co-channel interference visibility into NTSC and will reduce the peak-to-average power ratio by 1.5 dB.

3. DSC-HDTV Prototype Hardware Problems.

In addition to the improvements described above, the system tested at the ATTC suffered from two implementation problems. Both of these problems are mentioned in the ATTC report on DSC-HDTV, but they did not affect the performance of DSC-HDTV in the test center.

3.1. Slice Problem

The first problem was an occasional timing fault in the compressed video data deformatter which resulted in undetected errors in the decoding process for a given slice (64H x 48V pixel block). The decoder was unable to detect the error and therefore was unable to perform error concealment. These errors were also not predicted in the encoder loop which caused them to persist for several frames. The frequency of these "slice errors" ranged from one in several days, to a few per minute. Our work during the past several months has narrowed the problem down to a small section of the decoder, and reduced the frequency of the errors. A complete fix is not yet in hand, however, we expect to be able to correct this problem completely before November 15.

3.2. Half-Pel Problem

The other hardware problem affected the motion estimator during scenes with very high spatial frequency content. The calculation of block matching error on such scenes (e.g., high frequency zone plates) caused some error values to exceed the maximum value in an accumulator. This overflow condition in turn caused erroneous motion vectors to be computed for several 32Hx16V block positions in the scene. This problem was overcome by filtering the input to the motion estimator.

4. Summary and Quantification of Improvements

The following tables summarize the improvements and describe the effect of each improvement on the performance of the DSC-HDTV system:

PROBLEM	IMPROVEMENT	EFFECT ON PERFORMANCE
•Twinkle in stills	•Add new selection vectors	•No twinkle •Picture distortion drops by 30% with 100% 2-level data
•Block artifacts in high frequency zone plate	•Add new selection vectors •Proper selection of quantizers, perceptual weights, scale factors and VLCs	•Temporal frequency of zone plate can be increased by. factor of 3 without causing block artifacts •Spatial frequency of zone plate can be increased by factor of 3 without causing block artifacts
•"Breathing" in high frequency zone plate	•Replace mean offset with offset in leak calculation	•DC error variation removed •Overall picture quality improved •Drop in picture distortion by 50%
•Visible quantization error in saturated colors	•Proper selection of perceptual weights and scale factors for chrominance	•Greatly improved coding of saturated color
•Slow response on some difficult scene changes, e.g., flat field to high detail still or zone plate	•Proper selection of buffer control parameters •Improved deformatter efficiency •Better coding efficiency from better quantizers, perceptual weights and scaling	•Difficult scene changes settle imperceptibly
•Fading to gray during heavy channel impairments	•Set leak factor to one in decoder loop for replaced blocks	•Perfect error concealment for stills. •Much higher tolerance for channel errors in general when motion estimates are accurate
•Inadequate use of robust transmission for motion scenes	•Proper parameter settings for robust segment selection algorithm	•Amount of robust data needed to maintain a usable picture reduced by a factor of 2

Table 1. Summary of Improvements

PROBLEM	IMPROVEMENT	EFFECT ON PERFORMANCE
•Visible coding artifacts in complex scenes with source noise	•New selection vectors, quantizers, perceptual weights, scaling, leak calculation, and motion estimator filter •Addition of vertical noise coring.	•Block artifacts removed •Picture distortion reduced by 50%, or •Amount of 2-level channel data increase by 50% •For same amount of source noise, picture distortion goes down or bit-rate goes down, or for same distortion and bit-rate the tolerable amount of transmission noise goes up
•Slice errors	•Hardware fix in process	
•Half-pel problem	•Motion estimator filter	•No half-pel problem
•Overall picture quality	•All fixes above	•See Table 2
•Slightly degraded upper adjacent channel interference into NTSC	•Reduce pilot carrier level	•Upper adjacent channel interference into NTSC reduced by 3-6 dB •Eliminate unnecessary signal power
•Subdued vertical color stripe on co-channel into NTSC	•Additional 30 Hz carrier offset frequency	•Elimination of color stripe
•Luminance interference on Co-channel into NTSC	•Optimize dispersion	•Reduce peak-to-average power ratio by 1.5 dB.

Table 1. Summary of Improvements (Cont'd)

Based on the above improvements, a series of tests was run to quantify the overall improvement in the system. Table 2 and Figure 5 present the results of these measurements. As indicated in Section 2, we are currently optimizing the trade-off between picture quality and transmission performance for optimum soft-coding. After such a trade-off is completed, the precise improvement numbers may be slightly different. However, for the indicated number of binary segments, the following improvement numbers are accurate.

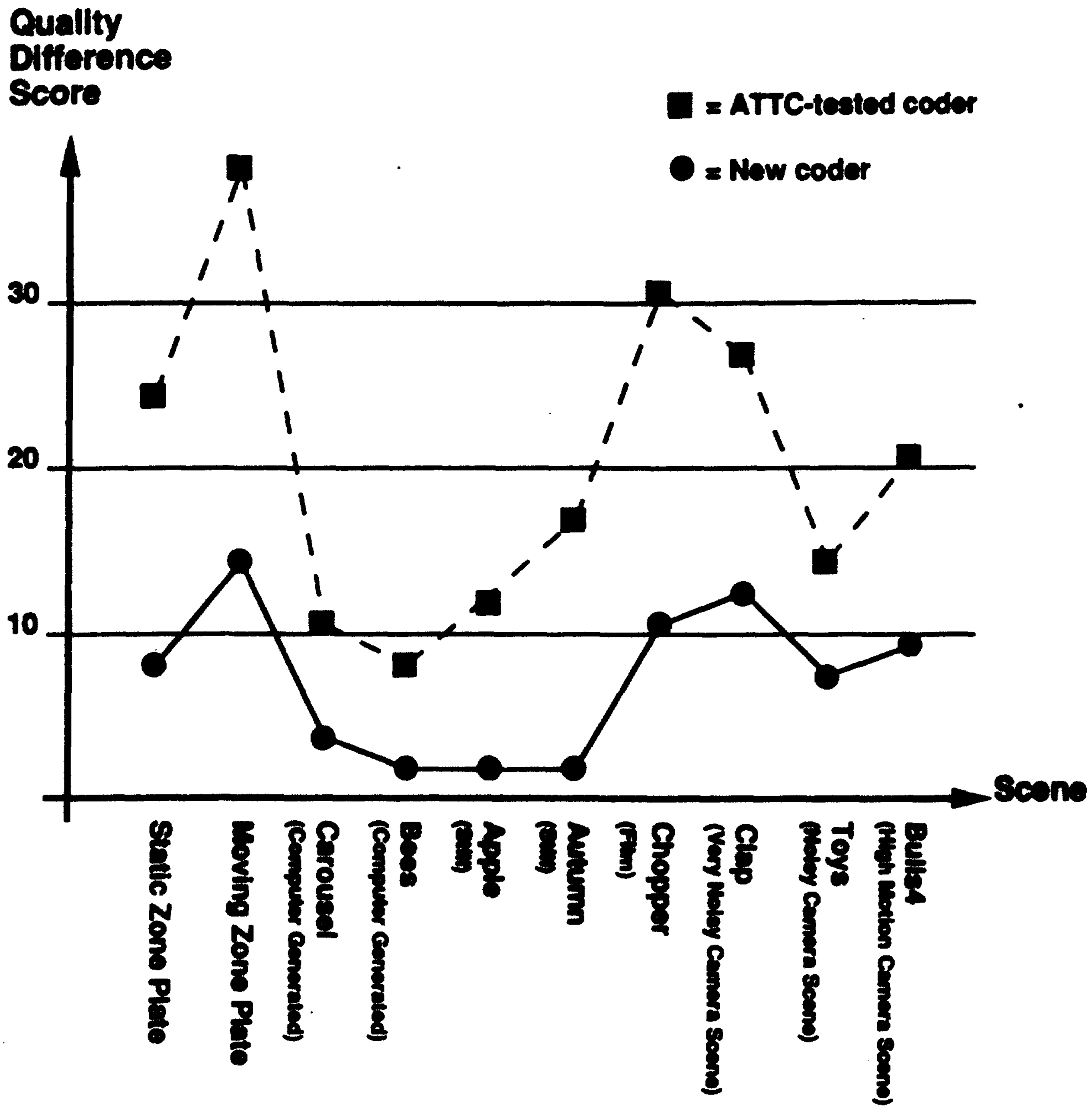
ITEM	ATTC-VERSION	IMPROVED VERSION
Scene change	Number of frames to recover fully	
Black to zone plate	83	7
Scene change every 20 frames	10	3
Overall quality	TD = Picture distortion N2 = # of 2-level segments	
Apple Tree (still)	TD = 35 N2 = 100	TD = 24 N2 = 100 .
Autumn Leaves (still)	TD = 34 N2 = 100	TD = 20 N2 = 100
Robots (still)	TD = 34 N2 = 110	TD = 21 N2 = 110
Train (still)	TD = 29 N2 = 110	TD = 16 N2 = 110
Glasgow Map (still)	TD = 44 N2 = 110	TD = 26 N2 = 110
Carousel (complex computer animated scene)	TD = 51 N2 = 20	TD = 45 N2 = 40
Bees (complex computer animated scene)	TD = 50 N2 = 23	TD = 43 N2 = 40
Lariat (60 Hz film sequence)	TD = 49 N2 = 20	TD = 50 N2 = 40
Chopper (film sequence)	TD = 45 N2 = 30	TD = 32 N2 = 40
Static zone plate	TD = 44 N2 = 38	TD = 16 N2 = 60
Moving zone plate	TD = 160 N2 = 20	TD = 49 N2 = 40
Bulls4 (high motion camera scene)	TD = 46 N2 = 40	TD = 43 N2 = 40
Bulls RP (high motion camera scene)	TD = 47 N2 = 35	TD = 40 N2 = 40

Table 2. Quantification of Improvements

ITEM	ATTC-VERSION	IMPROVED VERSION
Ability to handle source noise		
Static zone plate with noise	TD = 200 N2 = 20	TD = 53 N2 = 40
Moving zone plate with noise	TD = 235 N2 = 20	TD = 60 N2 = 40
Error concealment		0.5 to 1.5 dB advantage over ATTC-tested system
Channel change speed	1.5 second	0.5 seconds
Upper adjacent channel interference into NTSC		3-6 dB better
Signal power		0-4 dB better
Peak-to-average power ratio		1-1.5 dB better

Note: The total number of segments in a frame time could vary between 120 and 240, depending on what fraction is 2-level segments. The maximum number of binary segments (N2) could be 120. If, for example, the number of binary segments = 40, then 160 4-level segments will be available. TD is the picture distortion. It is the subjectively weighted mean square error between coded and uncoded picture. It is not always a perfect indication of picture quality, particularly if there is a peculiar visible coding artifact present in the picture. For example, the still scene "Apple" had a "twinkle" in the ATTC-tested coder, and therefore performed poorly in the quality measurement of Figure 5, even though its TD was not much different from that achieved by the improved coder.

Table 2. Quantification of Improvements (Cont'd)



Note: This graph was made by "informal" subjective tests. Three expert observers were used. Coded pictures from the ATTC-tested coder and the new coder were separately compared to the reference (uncoded 787 picture) and differences in quality scores were plotted. The scores are on a scale of 0 to 100, similar to one used by ATEL. A difference of 20 in score corresponds approximately to one point on a five-point comment scale.

Figure 5. Basic Picture Quality Improvement